JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2022, 23(9), 181–186
https://doi.org/10.12911/22998993/151885
ISSN 2299–8993, License CC-BY 4.0

Received: 2022.06.21
Accepted: 2022.07.08
Published: 2022.08.01

Influence of Agricultural Systems on Microbiological Transformation of Organic Matter in Wheat Winter Crops on Typical Black Soils

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ABSTRACT

The influence of different agriculture systems and measures of basic tillage on nutrient regime, its relation to the number of microorganisms involved in transformation of organic matter in typical black soils was studied. Direction of the formation processes of some physiological indices in the field of wheat winter was investigated. It was found that the most favorable conditions of nutrition and soil microflora development, as well as indices of crop growth and development are created when using ecological system of agriculture.

Keywords: nutritional regime, soil microbiological activity, agricultural systems, tillage, wheat winter.

INTRODUCTION

Today, great importance is given to the choice of optimal agriculture system which would ensure high and stable yields of agricultural crops under specific conditions [Andreyuk et al., 2001;Tsvey et al., 2008; Ivanyshyn et al., 2016; Kravchenko, 2020 Karbivska et al., 2022a]. At the same time, it should not only increase productivity of the fields, but also effectively prevent the spread of weeds, pests and pathogens of agricultural crops and contribute to creation of optimal plant nutrition conditions [Gudz et al., 2005; Balaev et al., 2013; Proposition, 2017; Parkhomenko, 2019; Hryhoriv et al., 2021; Parkhomenko et al., 2021; Karbivska et al., 2022b]. Currently, the main way of protecting crops is chemical methods, often without special control of standards and timing [Mazur, 2000; Tsyuk et al., 2018; Tsentilo, 2019; Karpenko et al., 2020; Karbivska et al., 2022]. In order to obtain the highest possible yield per unit area, economic limits for harm–making by weeds, pests and pathogens, as well as other major requirements of the regulations for usage of chemicals rarely taken into account [Rozhko and Makarenko, 2010; Piri et al., 2012; Balaev et al., 2013; Bakšienė et al., 2013; Long et al., 2018; Panchenko et al., 2019]. Such large–scale application of pesticides has led to pollution of environment as well as agricultural products with toxic substances which can lead to unpredictable consequences [Lü et al., 2019; Rika, 2019; Yakupoglu et al., 2021].

There is a clear trend around the world to reduction of pesticide load on production in order to reduce their accumulation in the environment [Patika, 2000; Gritsayenko et al., 2003; Koshytska et al., 2007; Ivanina, 2012; Keivanrad et al., 2012; Woźniak, 2019]. This is significantly facilitated, according to many scientists, by implementation of organic farming. The study of

its influence on the formation of plant nutrition regime and microbiological activity of soils is constantly kept in the field of view of modern scientific research and so far, there is no consensus concerning the use of industrial, ecological or biological systems of agriculture. Therefore, the research in this direction is relevant [Shikula, 1998; Gritsayenko et al., 2003; Ivanyshyn et al., 2016; Landré et al., 2020].

MATERIAL AND METHODS

The aim of the research was to determine the most effective system of agriculture for growing winter wheat under the conditions of the Right–Bank Forest-Steppe of Ukraine, aimed at preserving and reproducing soil fertility.

To achieve this aim, it was planned to determine the ratio of ecological and trophic groups of the microorganisms involved in transformation of organic matter, general regularities of directing microbial processes of this transformation in the soil and their relation to accumulation and use of nutrients in the field of winter wheat, and analyze the indices of winter wheat growth and development on the background of different nutrition and measures of basic tillage.

To solve this aim, research was conducted in the stationary field experiment at the Department of Agriculture and Herbology. It includes studying of two factors: different measures of basic tillage in five-field grain-weeding crop rotation and three systems of agriculture: industrial, ecological and biological. Soil difference in the experimental field is represented by typical low–humus coarse–dusty–loamy black soil with composition of physical clay – 37% and sand – 63%. Specific mass of solid phase of the soil is 2.66 g/cm^3, density in equilibrium is 1.16–1.25 g/cm^3, humidity of persistent withering is 10.8%, humus content in the 0–10 cm layer is 4.53%, in 35–45 cm – 4.38%, pH of salt extract – 6.87, and absorption capacity – 31.9 mg/eq. per 100 g. of soil.

The scheme of experiment is the following: factor A – farming systems. Industrial system of agriculture (control) for restoring soil fertility consisted of 300 kg of mineral fertilizers ($N_{92}P_{180}K_{108}$) and 12 tons of organic matter per 1 ha of crop rotation area with intensive application of pesticides. The ecological system consisted of 24 t of organic matter application, comprising 12 t ha^{-1} of manure, 6 t ha^{-1} of by-products and 6 t/ha of green siderates, as well as 150 kg of mineral fertilizers ($N_{46}P_{49}K_{55}$) with standard application of pesticides. The biological system included application of only natural organic fertilizers in the amount of 24 t ha^{-1} for restoring soil fertility without introduction of industrial agrochemicals, as well as biological products to optimize plant nutrition and biological plant protection products against pests.

Factor B – measures of basic tillage. During crop rotation, differentiated tillage for each crop (control) included: one flat–cut loosening for barley, two surface tillages with disc implements for winter wheat (predecessor – peas for grain) and includes six plows of different depths for row crops. Surface tillage is 8–10 cm disking for all crops of crop rotation. The experiment was repeated four times. The area of sown plot is 280 m^2, and the accounting area – 240.

The laboratory experiments were carried out on the basis of the Ukrainian Laboratory of Quality and Safety of Agricultural Products in accordance with the generally accepted current methods and standards [Ushkarenko et al., 2014].

RESULTS AND DISCUSSION

The content of nutrients in the soil in a form available for use by plants is often one of the most determining factors in crop yield formation. According to the data in Tables 1 and 2, the content of nutrients in the soil was significantly affected by both agricultural systems and basic tillage measures. In particular, at the time of crop sowing the soil contained a sufficient amount of nutrients for all variants of the experiment. However, the variants with ecological system of agriculture, the content of nitrate nitrogen, movable phosphorus and exchangeable potassium was higher in comparison with industrial and biological systems. The amount of nitrogen differed, especially significantly in biological system of agriculture, where it was the lowest. Plowing of siderates and post–harvest residues of winter wheat predecessor, i.e. peas, into the soil promotes more intensive assimilation of nitrogen compounds.

While analyzing the influence of basic tillage measures on the content of nutrients in it, it can be concluded that when applying control variant of tillage measure, there appears a trend to provide higher indices of nitrate nitrogen, movable phosphorus and exchange potassium in ecological system of agriculture. When using surface tillage in the

Table 1. Content of available forms of nutrients in 0–30 cm layer of soil when sowing wheat winter, mg/eq per 1000 g of soil

Agriculture system	Measures of soil tillage	Nitrate nitrogen	Movable phosphorus	Exchange potassium
Industrial	Differentiated (control)	52	88	80
	Surface	47	75	71
Ecological	Differentiated	63	115	93
	Surface	59	105	83
Biological	Differentiated	45	94	85
	Surface	42	86	74

Table 2. Content of available forms of nutrients in 0–30 cm layer of soil in the earing phase of wheat winter, mg/eq per 1000 g of soil

Agriculture system	Measures of soil tillage	Nitrate nitrogen	Movable phosphorus	Exchange potassium
Industrial	Differentiated (control)	41	85	65
	Surface	40	70	57
Ecological	Differentiated	59	108	87
	Surface	55	88	77
Biological	Differentiated	36	89	72
	Surface	39	75	62

upper 0–10 cm layer of soil, there is a higher content of nutrients, but it decreases in the arable layer.

In the earing phase, the crop used a certain amount of nutrients from the soil, but the nature of their distribution remained the same as at sowing time. To identify the impact of the studied farming systems on peculiarities of growth and development of winter wheat plants, some physiological indices of this crop were observed (Table 3).

It was found that the length of aboveground part of winter wheat plants was the highest in the ecological system of agriculture – 92.10, which is 3.53 cm higher than in the same control variant in industrial system of agriculture. During surface soil tillage in the same system, the plants were also 2.62 cm taller than in the control. The lowest length of aboveground mass of winter wheat plants was in the biological system – 1.33 for differentiated and – 8.78 cm for surface tillage.

The number of leaves per 1 stem of the crop, and leaf surface index of winter wheat in the flowering phase were also higher in ecological system on differentiated soil tillage (Table 3). It is known that plant growth and development is influenced by a set of indices, but, in authors' opinion, they are also greatly influenced by the content of nutrients in available forms, phytotoxicity of soil, direction of microbiological processes and absence of pests. Obviously, the usage of ecological agriculture system has a positive impact.

To assess the impact of agricultural systems and various measures of basic tillage, it is necessary to determine the number of microorganisms that are part of different systematic groups. In particular, autotrophic microorganisms are part of the microbial coenosis of soil and they are slow-growing microorganisms and are able to absorb specific humus substances. Oligotrophic

Table 3. Indices of wheat winter growth and development in the flowering phase depending on agricultural systems

No.	Agriculture system	Measures of soil tillage	Number of leaves per 1 stem, pcs	Index of leaf surface	Length of aboveground parts, cm
1	Industrial	Differentiated (control)	4.5	5.3	88.57
		Surface	4.2	5.0	88.32
2	Ecological	Differentiated	4.7	5.8	92.10
		Surface	4.5	5.5	91.19
3	Biological	Differentiated	4.1	4.9	87.24
		Surface	3.9	4.7	79.79

microorganisms are able to actively exist under the conditions of insufficient energy and nutrition. Pedotrophic microflora is able to combine microorganisms of autotrophic and oligotrophic groups. Ammonifying microorganisms show the process of decomposition of organic nitrogen–containing compounds to ammonia.

Structure analysis for microbial groups was conducted according to the number ratio of microorganisms of individual ecological and trophic groups which allowed revealing the fact that these indices varied significantly depending on the studied crop, farming system and main tillage (Table 4).

In the flowering phase of winter wheat, mineralization coefficient was highest in the biological system of agriculture with surface tillage (1.90) and in the industrial system of agriculture with differentiated tillage (1.67), which indicates intensity of organic matter mineralization of the soil, active use by microorganisms of mineral forms of nitrogen resulting in its reduced absorption by plants. Under such conditions, a loss of soil organic matter occurs. In the ecological system of agriculture, mineralization coefficient is much lower and does not exceed 1. This process has a positive effect on accumulation of organic matter in the soil and mineral nitrogen which is formed during ammonification.

Increase of pedotrophic index indicates improved decomposition intensity of soil organic matter, in particular humus compounds, and increase in soil oligotrophy indicates a decrease of the nutrient content in soil. In the cases of industrial and biological farming systems with surface tillage pedotrophic coefficient was the highest (0.37 and 0.38, respectively). In the ecological system of agriculture with differentiated tillage, this index was the lowest (0.16), which indicates preservation of soil organic matter under these conditions.

Coefficient of microbial transformation of organic matter, which determines biogenicity of soil, was the highest in the ecological system of

Table 4. Ratio of microorganism number of different ecological and trophic groups in winter wheat crops in the flowering phase

Experiment variants	Index of mineralization and mobilization	Pedotrophic coefficient	Oligotrophic coefficient	Index of microbial transformation of soil organic matter
Differentiated soil tillage (control)				
1. Industrial system of agriculture (control)	1.67	0.32	0.53	30.40
2. Ecological system of agriculture	0.50	0.16	0.37	101.67
3. Biological system of agriculture	1.36	0.30	0.63	19.07
Surface soil tillage				
4. Industrial system of agriculture (control)	1.10	0.37	0.22	52.90
5. Ecological system of agriculture	0.82	0.21	0.63	45.79
6. Biological system of agriculture	1.90	0.38	0.93	10.68

Table 5. Orientation for coefficients of microbiological processes of typical black soil in wax ripeness phase of winter wheat

Experiment variants	Mineralization index	Pedotrophic coefficient	Oligotrophic coefficient	Index of microbial transformation of soil organic matter
Differentiated soil tillage (control)				
1. Industrial system of agriculture (control)	1.44	0.36	0.21	25.38
2. Ecological agriculture system	1.14	0.33	0.09	40.04
3. Biological agriculture system	1.47	0.42	0.18	24.12
Surface soil tillage				
4. Industrial system of agriculture (control)	1.73	0.32	0.18	32.64
5. Ecological agriculture system	1.29	0.22	0.19	40.18
6. Biological agriculture system	1.23	0.35	0.15	72.65

agriculture with differentiated tillage and amounted to 101.67. This index was the lowest in the biological and industrial systems of agriculture with differentiated tillage (19.07 and 30.40 respectively).In the phase of wax ripeness, the highest rates of mineralization were recorded in the industrial system of agriculture with surface tillage – 1.73 and the biological system with differentiated tillage achieved 1.47 (Table 5).

In the ecological system of agriculture mineralization coefficient in the flowering phase of winter wheat is 1.14 for differentiated tillage and 1.29 for surface tillage. An increase of organic matter mineralization at the end of winter wheat vegetation contributes to "biological consolidation" of mineral nitrogen which is not lost from the soil.In the phase of wax ripeness, a change in the dynamics of pedotrophic coefficient is also observed. Thus, it is highest in the biological and industrial systems of agriculture with differentiated tillage (0.42 and 0.36 respectively). The lowest pedotrophic coefficient (0.22) was found in the ecological system of agriculture with surface tillage. Oligotrophic coefficient at the end of vegetation decreases in all variants of the experiment. This indicates an increase of easily digestible nutrients in the soil. It was the lowest in an ecological system of agriculture with differentiated tillage – 0.09.

Crop yields are the main index of effective soil fertility and human economic activity. According to the results of the research, the yield of winter wheat is largely dependent on the measures of basic tillage and farming systems. The highest grain yield was recorded In the ecological system of agriculture with differentiated tillage – 5.8 t ha^{-1}, and in the industrial system 5.5 t ha^{-1}. The lowest yield of this crop was obtained in the variant with the use of surface tillage (5.2 t ha^{-1} and 5.0, respectively).

CONCLUSIONS

Thus, application of the ecological system of agriculture with both surface and differentiated tillage creates favorable agrochemical and microbiological conditions in soil which allowed plants to form more developed aboveground part and in particular leaf apparatus. Reduction of chemical pesticides and mineral fertilizers had a positive effect on the indices of mineralization, transformation of nutrients, ratio of ecological and trophic groups of microorganisms.

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